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ABSTRACT

The construct underlying simple paper-and-pencil logical operations tasks administered to young children in group settings was examined. The logical operations, number concepts, and visual discrimination subtests of the Early School Assessment (ESA) were administered as part of the Fall 1987 national tryout of the ESA. The mathematics concepts and applications subtest of the California Achievement Test (Form E) was administered as an anchor. The two subtests of ESA Level 1 was administered to 766 and 1,456 beginning kindergarten students and the three subtests of ESA Level 2 was administered to groups of 1,553, 1,728, and 888 first graders. It was hypothesized that the logical operations items in the ESA could be aligned with either visual discrimination tasks or with mathematics. An item analysis was conducted. All three ESA subtests were highly correlated with the mathematics test. The analysis revealed that these paper-and-pencil logical operations items were more closely related to number concepts than to visual discrimination, but they were distinct. These paper-and-pencil operations were not highly correlated with more traditional tasks involving manipulatives, suggesting that different constructs were being measured. The mode of response is a critical issue in the assessment of logical operations in young children; this issue raises questions of construct validity. Six tables present study data. (SLD)

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Paper-pencil methodology in the assessment of logical operations in children

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The purpose of this study is to examine the construct that underlies simple paper-and-pencil logical operations tasks administered to young children in group settings. "A construct is an intellectual device by means of which one construes events. It is a means of organizing experience into categories." (Cronbach, 1971, p. 464) In this study, the construct of logical operations in young children is defined by three tasks: grouping items with a common attribute, ordering objects by size, and matching equivalent sets. These tasks have long been associated in the literature with mathematical ability (Clements, 1984; Flavell, 1985; Gelman & Baillargeon, 1983; Markman, 1979; Souvinly, 1980). However, these tasks have also traditionally been individually assessed using concrete, manipulative objects. The use of paper-pencil methodology gives rise to the question of whether the tasks are more closely aligned with visual discrimination. In addition, the assessment of kindergarten and first grade children in group settings using paper-pencil tasks raises a fundamental question of validity among early childhood professionals. Under such circumstances, what is really being measured: test-taking ability or the intended construct? (National Association of Early Childhood Specialists in State Departments of Education, 1987; National Association for the Education of Young Children, 1988; National Association of State Boards of Education, 1988) In order to investigate these questions, two approaches were taken: (1) an item analysis of paper-pencil items designed to measure logical operations using the three-parameter logistic model and (2) a comparison of these paper-pencil tasks with more traditional individually-administered tasks involving manipulatives.

METHOD

The Logical Operations, Number Concepts, and Visual Discrimination subtests of the Early School Assessment (ESA) were administered as a part of the Fall, 1987 national tryout phase of the ESA. The Mathematics Concepts and Applications subtest of the California Achievement Test Form E (CAT E) was included as an anchor. ESA Level 1 was administered to beginning kindergarten students, and ESA Level 2 was administered to beginning first grade students.

The majority of items have three answer choices; the 20 CAT items have four answer choices. The logical operations item types include ordering objects by size, grouping items with a common attribute, and matching equivalent sets. The number concepts items assess number/numeral correspondence, quantitative language concepts, counting, addition, and subtraction. The visual discrimination items at the first grade level are patterns and embedded patterns. Table 1 contains the number of items and examinees at each grade level.

It was hypothesized that the logical operations items in the ESA could be aligned either with visual discrimination tasks or with mathematics. In order to investigate these two hypotheses, tryout items were combined so that logical operations items were grouped with number concepts as well as with visual discrimination items.

An item analysis using LOGIST (a three-parameter item response theory program) was conducted. All three ESA subtests were highly correlated with CAT/E Mathematics Concepts and Operations (see Table 2). In order to determine if logical operations items scaled with number concepts or with visual discrimination, the logical operations items were grouped with each subtest, thereby defining two distinct constructs. Once the construct defined by these items was removed (indicated by a mean correlation of error equal to zero), a correlation matrix of residuals of each subset was examined in order to determine if more than one construct were present within each grouping. A Q3 (chi-square) fit statistic was used to analyze the degree of error in the construct defined by the items, i.e. which items were influenced by an alternative factor or had similar content (Yen, 1984). The expectation is that the Q3 would be 0 if only one construct were being defined. If correlations are highly positive within a set of items but negative or equal to zero between sets, there is evidence of systematic error, and distinct constructs may be present. The rule of thumb is if the mean correlation of error in the residuals is greater than .04, the correlation is significantly positive.

RESULTS

Tables 3 and 4 contain the mean correlations of error within sets for number concepts at the kindergarten and first grade levels. Table 5 contains the mean correlations of error within sets for visual discrimination at the first grade level (data for the kindergarten level is not available).

At both the kindergarten and first grade levels, once the number concept construct is removed, the correlations are highly positive within each subset of logical operations items; the correlations between sets are negative as well. The same holds true to an even greater extent for the visual discrimination construct, indicating that logical operations scales better with number concepts than with visual discrimination. However, the high correlations within the logical operations subsets themselves indicate that ordering by size, equivalence, and grouping may form distinct constructs. The Kruskal-Wallis Significance Tests reporting the Q3 statistics in Tables 3 through 5 indicate the magnitude of these effects.

In order to further investigate what is being measured, the ESA Logical operations subtest, along with similar tasks involving manipulatives, was administered to a nationally representative sample of kindergarten students during fall standardization

(1988) (N = 750). An examination of the correlation matrix (see Table 6) reveals small but significant correlations. The set equivalence items are more highly correlated with counting (r = .41, p < .0001) and number/numeral correspondence (r = .44, p < .0001) manipulative tasks than with traditional conservation of number tasks (r = .18, p < .0001).

CONCLUSIONS

These paper-pencil logical operations items are more closely related to number concepts than to visual discrimination, yet they are distinct. These paper-pencil logical operations tasks are not highly correlated with the more traditional tasks involving manipulatives, suggesting that different constructs are being measured. The mode of response is a critical issue in the assessment of logical operations in young children and raises a fundamental question of construct validity. Whether the mode of response is as important a measurement question in other domains within early childhood assessment remains to be determined.

Table 1

Number of Items and Examinees

	Number of Items	N
Logical Operations		
Kindergarten	25	766
First Grade	25	1553
Number Concepts		
Kindergarten	37	1456
First Grade	52	1728
Visual Discrimination		
First Grade	43	888

Table 2

Correlation of ESA subtests with CAT/E Mathematics Concepts and Applications

ESA Subtests	CAT/E Mathematics
Logical Operations	
Kindergarten	.544
First Grade	.485
Number Concepts	
Kindergarten	.596
First Grade	.648
Visual Discrimination	
First Grade	.412

Note. All correlations are significant, $p < .0001$.

Table 3

Kruskal-Wallis Significance Tests and Mean Correlations of Error Within Sets After Effect of Construct is Removed for Number Concepts at the Kindergarten Level

	Number Concepts	Ordering	Equivalence	Grouping
Number Concepts	.00	-.03	-.04	-.05
Ordering		.14	-.05	-.01
Equivalence			.13	-.04
Grouping				.22

Kruskal-Wallis Significance Tests

within vs. between for Q3,	chi-square with 1 df	235.04
within sets only for Q3,	chi-square with 3 df	181.02
between sets only for Q3,	chi-square with 5 df	86.60

Table 4

Kruskal-Wallis Significance Tests and Mean Correlations of Error Within Sets After Effect of Construct is Removed for Number Concepts at the First Grade Level

	Number Concepts	Ordering	Equivalence	Grouping
Number Concepts	.01	-.05	-.04	-.03
Ordering		.20	-.06	-.04
Equivalence			.21	-.02
Grouping				.10

Kruskal-Wallis Significance Tests

within vs. between for Q3,	chi-square with 1 df	470.55
within sets only for Q3,	chi-square with 3 df	155.77
between sets only for Q3,	chi-square with 5 df	60.08

Table 5

Kruskal-Wallis Significance Tests and Mean Correlations of Error Within Sets After Effect of Construct is Removed for Visual Discrimination at the First Grade Level

	Patterns	Embedded Patterns	Ordering	Equivalence	Grouping
Patterns	.05	-.02	-.02	-.03	-.02
Embedded Patterns		.02	-.08	-.07	-.03
Ordering			.32	.01	.02
Equivalence				.36	.01
Grouping					.12

Kruskal-Wallis Significance Tests

within vs. between for Q3,	chi-square with 1 df	426.73
within sets only for Q3,	chi-square with 3 df	171.22
between sets only for Q3,	chi-square with 5 df	527.02

Table 6

Correlations of DSC & ESA Mathematical Concepts & Logical Operations Objectives

Fall Standardization K.2 N = 750

	DSC (manipulatives)				
ESA (paper/ pencil)	Counting	Number/ Numeral	Classify	Conserve	Seriate
Group (Classify)	.21	.18	.08	.03	.17
Set Equivalence (Conserve)	.41	.44	.15	.18	.32
Order (Seriate)	.11	.13	.09	.12	.26

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